By Roger Melen and Harry Garland

BUILD THE FIL-OSCILLATOR

IT'S A TWOSOME: SHARP AUDIO FILTER & VERSATILE WAVEFORM GENERATOR

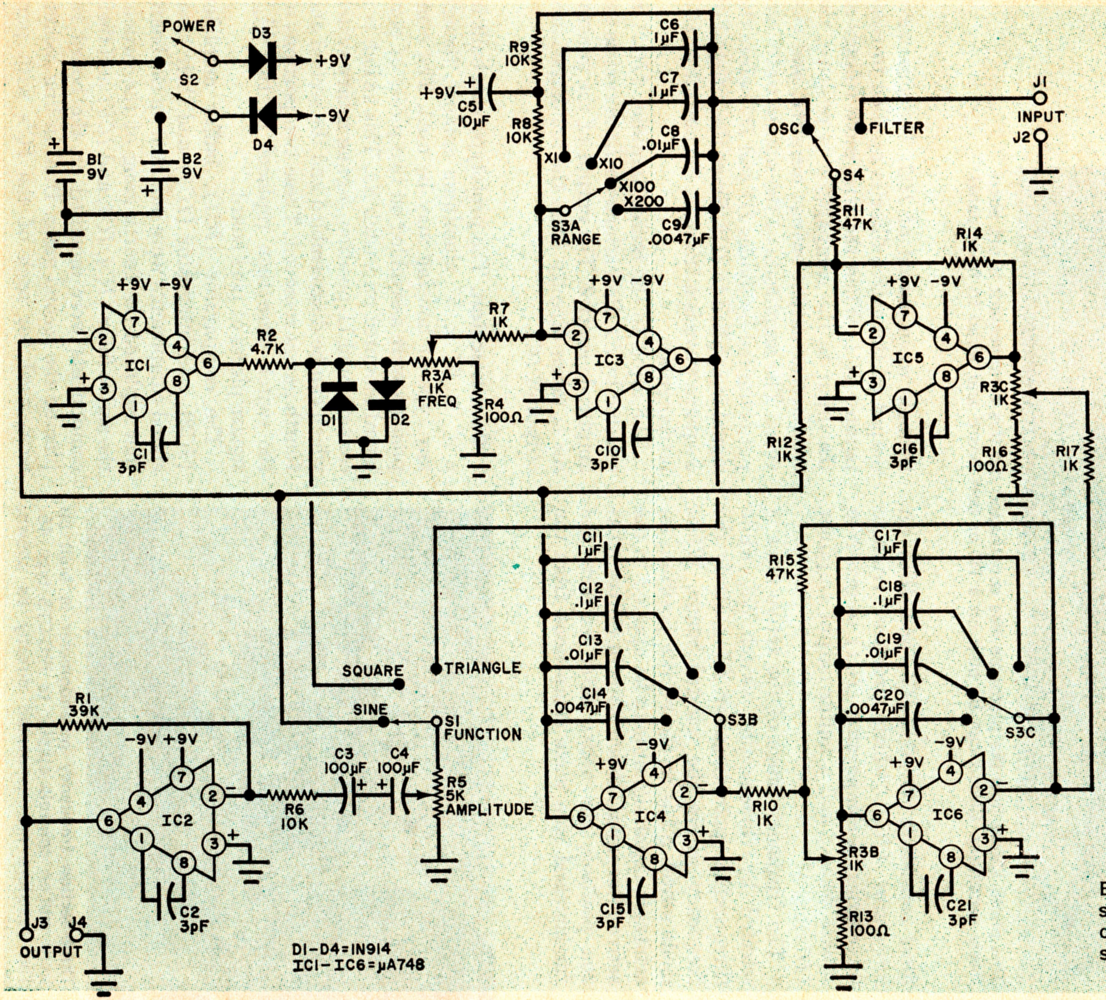
ACTING just as if it were born under the zodiacal sign of Gemini (the twins), the Fil-Oscillator is an unusual laboratory instrument having two distinct personalities: it is both a high-Q audio filter and a low-distortion sine, square or triangle wave generator. (Detailed specifications are given in the Table.)

The heart of the Fil-Oscillator circuit (see schematic) is a sharp active filter (using three op amps) which can be tuned over the audio spectrum. Since all non-sinusoidal waveforms can be broken down into their constituent sine wave elements, it doesn't matter what shape is applied to the input of the filter. A sine wave of the frequency to which the filter is tuned appears at the output. Because of this sharp filtering action, the filter can be used in a wide number of audio frequency applications, including measurement of the overtones (harmonics) of a musical instrument, charting the frequency spectrum of a complex waveform, measurement of the harmonic distortion of an amplifier or speaker system, or boosting the selectivity of a ham or SWL receiver.

As an oscillator, the device serves as a function generator of laboratory quality, developing low-distortion sine, square, or triangle waves which are very useful in various test procedures. The Fil-Oscillator's active filter is used to derive the sine waves producing a purer waveform than is possible in conventional waveshaping circuits.

Six inexpensive IC op amps are used in the Fil-Oscillator, and its total cost is about $35.

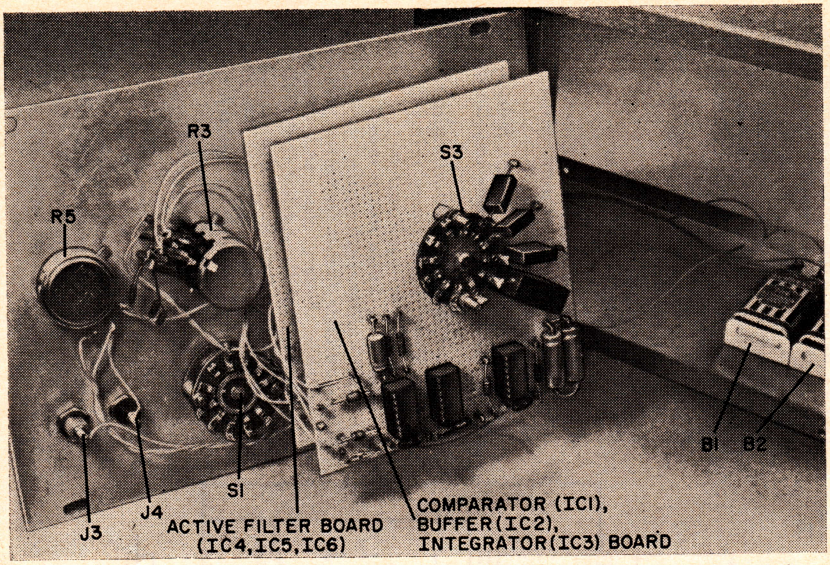
Theory of Circuit Design. The Fil-Oscillator is in four functional sections: an active



PARTS LIST

B1,B2—9-volt battery
C1,C2,C10,C15,C16,C21—3-pF capacitor
C3,C4—100-µF, 6-volt electrolytic capacitor
C5—10-µF, 12-volt electrolytic capacitor
C6,C11,C17—1-µF Mylar capacitor
C7,C12,C18—0.1-µF Mylar capacitor
C8,C13,C19—0.01-µF Mylar capacitor
C9,C14,C20—0.0047-µF Mylar capacitor
D1-D4—1N914 diode
IC1-IC6—Op amp integrated circuit (Fairchild µA748)
J1-J4—Five-way binding post
R1—39,000-ohm, ¼-watt resistor
R2—4700-ohm, ¼-watt resistor
R3—1000-ohm, 3-gang potentiometer
R4,R13,R16—100-ohm, ¼-watt resistor
R5—5000-ohm potentiometer
R6,R8,R9—10,000-ohm, ¼-watt resistor
R7,R10,R12,R14,R17—1000-ohm, ¼-watt resistor
R11,R15—47,000-ohm, ¼-watt resistor
S1—3-position, 1-pole rotary switch
S2—Dpst slide or toggle switch
S3—4-position, 3-pole rotary switch
S4—Spdt slide or toggle switch
Misc.—Suitable chassis (see text), perf board and clips, battery clips and connectors, knobs (4), handle and feet (optional).
Note—The set of six integrated circuits can be obtained from Schweber Electronics, Order Dept., Westbury, NY 11590 for $8.80, including postage and handling. Ask for µA748 dual in-line commercial grade IC's.

Besides serving as a function generator having sine, square, or triangle wave output, the circuit also includes a unique tunable active filter suitable for any type of waveform analysis.

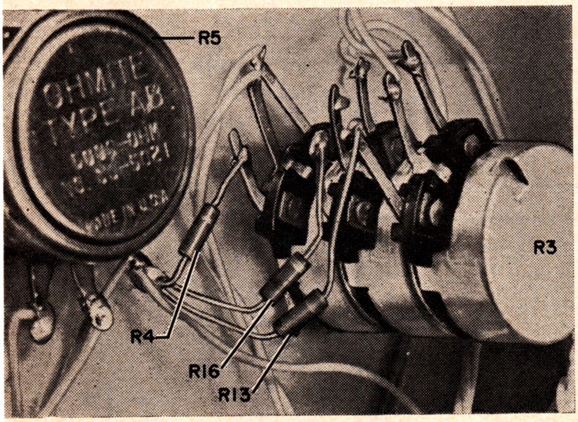


This photo shows how the prototype was constructed but this arrangement is not absolutely necessary. Circuit can be built on a PC or perf board and wired to front panel.

filter consisting of *IC4*, *IC5*, and *IC6*; an integrator (*IC3*) which produces triangle waveforms; a comparator (*IC1*) to generate square waves; and a buffer output amplifier (*IC2*).

The frequency range of the active filter is selected by three-section switch *S3*, while three-section potentiometer *R3* controls the frequency within the selected range. When mode switch *S4* is in the FILTER position, an arbitrary input signal may be applied to the active filter input. When *S4* is in the OSCILLATOR position, the active filter extracts the fundamental sine wave component from the triangle wave output of *IC3*. The sine wave output of the active filter is applied to comparator *IC1*. When the sine wave voltage at the input to the comparator is positive, the comparator output swings negative, and vice versa. The amplitude of the square wave output is limited by diodes *D1* and *D2* before the signal is applied to *IC3*. Since the integral of a square wave is a triangle, the output of *IC3* is triangular.

The input to the buffer amplifier (*IC2*) is selected by *S1*. Potentiometer *R5* serves as the amplitude control. The output of the generator is taken directly from the low-impedance output of *IC2*.



Three-section frequency potentiometer is built up from add-on controls similar to IRC-CTS type 45. The resistors are connected directly as shown.

Construction. The prototype was built in a 9″ × 6″ × 5″ aluminum cabinet, though any type of housing may be used. The components were assembled on two pieces of perf board mounted on switch *S3*. This switch is a conventional 11-position, 5-gang rotary switch which can be disassembled and the second and fourth gangs removed. These two portions of the switch were then replaced by two 4¾″ square pieces of perf board.

The comparator (*IC1*), buffer amplifier (*IC2*), and integrator (*IC3*) and their associated components were mounted on the board that replaced the fourth gang of the switch; the active filter (*IC4*, *IC5*, and *IC6*) and their components were mounted on the board replacing the second gang. Dual in-line sockets were used for each of the IC's with perf

HIRSCH-HOUCK LABORATORIES
Project Evaluation

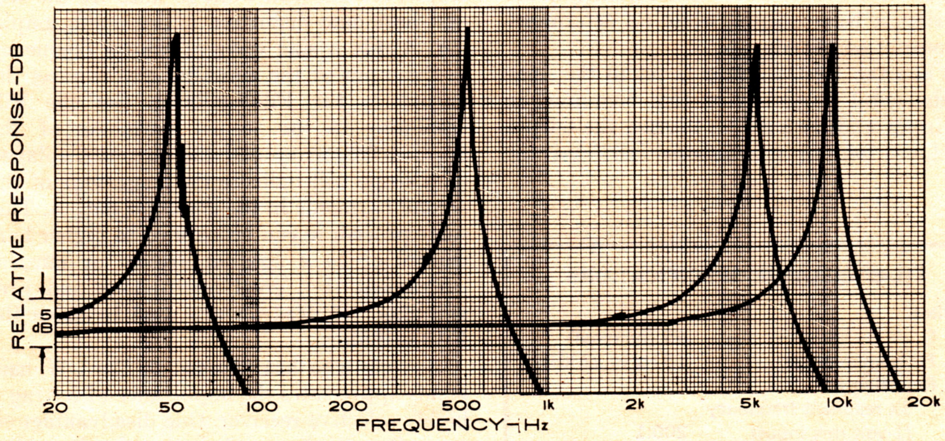
This is a very useful instrument for an audio engineering laboratory and, in a simplified form (with just the filter), it would be a valuable addition to any amateur radio shack.

In the filter mode over the audio range, the pass-band gain of the filter varied less than 2.0 dB. Rejection of frequencies higher than that to which the filter was tuned was a little better than claimed with the third harmonic being attenuated by 49 dB at a fundamental of 1000 Hz. Rejection at lower frequencies was not as good as claimed by the author. At one-third of the filter frequency, the response was down 29.5 dB versus 35.5 dB given by the author. The noise output of the filter was 0.9 mV and appeared to be essentially independent of the level control setting. This would indicate that the noise is being generated after the level control in the output stage. An input of 0.38 volt is required for the filter to deliver 1.0 volt output at 1000 Hz. The maximum output before clipping in IC2 is 4.4 volts rms (high-impedance load).

To check the effectiveness of the filter in reducing distortion from a test oscillator, the output of a Radford low-distortion oscillator was fed through the Fil-Oscillator. At 1000 Hz, the input signal was 0.14% distortion, but after passing through the Fil-Oscillator, the distortion was 0.014%.

In the oscillator mode, the output amplitude varied from 1 to 2 dB over the full range and harmonic content was low at all frequencies—typically slightly under 0.05% up to 1000 Hz and about 0.07% in the 10-kHz to 20-kHz region. Distortion was essentially all third harmonic. The square wave does not have an ideal shape and has a noticeable tilt. The rise time was about 5 microseconds. At audio frequencies, the triangular wave appeared good, but at very high frequencies there was distortion visible.

The filter mode may be used to add audio selectivity to any communications receiver utilizing a narrow bandwidth. It is possible to copy CW signals through considerable QRM and QRN.



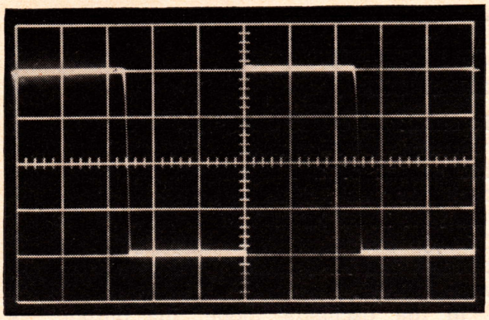
board clips to hold the passive components.

The various controls should be mounted on the front panel and the batteries on the bottom of the chassis.

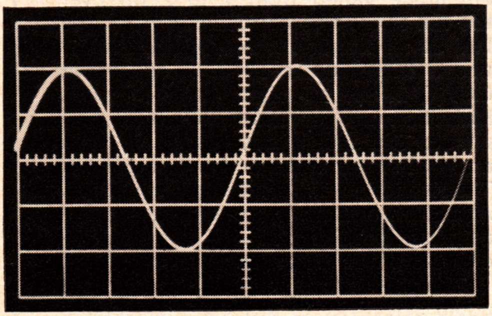
Label the controls on the front panel with transfer type covered with a clear plastic spray. Add a handle and rubber feet to improve the utility and appearance.

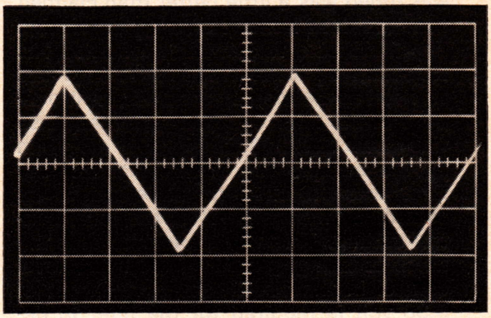
Calibration. Potentiometer *R3* can be calibrated by comparing the output of the Fil-Oscillator with that of a known audio frequency on an oscilloscope. A conventional audio generator and a frequency counter can be used to set the exact horizontal amplifier frequency if you want a more exact calibration. As each frequency is found, mark the position of *R3*. Once one range has been calibrated, and if high-quality Mylar capacitors have been used, the other ranges should fall in step with the markings.

Operation. The frequency range is selected by switch *S3* (RANGE) with the actual



Of the three functions provided by the generator, the square wave (left) and the sine wave (below left) are the most useful in test applications. The triangle wave (below) is a special type of waveform used in vibration studies, servo applications, medical research, etc. Note that the 3 waveforms are clean and show no signs of distortion. The thickening of the trace on the left side is a malfunction of the oscilloscope used.





frequency determined by the setting of *R3*. Switch *S1* is used to select either a sine, square or triangle wave output, while *R5* determines the output amplitude.

When the Fil-Oscillator is set to the same fundamental frequency as that contained in the input and with *S4* on FILTER, the output displayed on an oscilloscope indicates the level of the fundamental waveform. For example, assume you want to measure the second harmonic distortion of an audio amplifier. Apply a sine wave of known frequency to the input of the amplifier and connect the output to the Fil-Oscillator. Set the Fil-Oscillator to the second harmonic of the applied frequency and the output displayed on a scope will indicate the magnitude of the second harmonic in the amplifier output. This same procedure can be applied to higher harmonics or to a speaker system or musical instrument if a good microphone and preamplifier (if needed) are used to drive the Fil-Oscillator.

Anyone who has listened to the CW ham bands appreciates the importance of having a highly selective receiver. One disadvantage of using Q multipliers and similar circuits is that the selectivity control is very "touchy." Since the Fil-Oscillator has a constant, rather than a variable, Q, it is much easier to use. Simply connect the audio output of the receiver to the Fil-Oscillator input and set the filter frequency to obtain some pleasing tone. Only CW signals of that frequency (using the receiver BFO, of course), will pass through the filter—the others being rejected. This may show up drift in the receiver as well as the BFO. The output of the Fil-Oscillator can be connected to any external audio amplifier or to a headset. —30—

FIL-OSCILLATOR SPECIFICATIONS

Filter	
Q	45 (nominal)
Frequency range	15 Hz to 32 kHz
Rejection at 3X resonant frequency (1-volt rms input)	200:1
Rejection at ⅓X resonant frequency (1-volt rms input)	60:1
Noise output	less than 0.5 mV rms
Oscillator	
Output waveforms	sine, square, triangle
Frequency range	15 Hz to 32 kHz
Output amplitude	0 to 4 volts peak-to-peak
Output impedance	100 ohms
Output protection	short-circuit proof